APPENDIX D

Scoping Study Area 1 and 2 Hydrodynamic Model Development

Introduction

This appendix details the work done to create preliminary conceptual level models for the Tittabawassee River and Floodplain Scoping Study (Scoping Study) for Area 1 and Area 2 on the Tittabawassee River and floodplain. These models were created to help develop a conceptual understanding of river and floodplain hydraulics and sediment transport flow paths under low and high flow conditions at Area 1 and Area 2. The two-dimensional hydrodynamic model for each area was developed using the Environmental Fluid Dynamics Code (EFDC) model, a hydrodynamic modeling framework developed by the U.S. Environmental Protection Agency (USEPA) that has been applied to simulate many riverine systems throughout the United States (USEPA, 2001). EFDC is a state-of-the-art model that can be used to simulate aquatic systems in one, two, or three dimensions. It is one of the most widely used and technically defensible models available. The EFDC model also allows for wetting and drying of shallow areas through the use of a mass conservation scheme, making it particularly well suited for simulating the floodplain hydrodynamics of the Tittabawassee River and floodplain. This appendix describes the steps taken to create these models including grid development, roughness estimates, development of model topography and bathymetry, boundary conditions, and the conceptual model simulations performed to date. All steps taken and data used are considered to be preliminary estimates and model results and conclusions should be considered draft.

Model Grid Development

For this initial effort, hydrodynamic models were built that encompassed Area 1, located on The Dow Chemical Company (Dow) property downstream of Gordonville Road, and Area 2, which is located within Imerman Park. Model grids for both areas were developed using the grid development program SeaGrid, developed by the United States Geological Survey (USGS) for use in the program Matlab. The SeaGrid program allows the user to develop curvilinear or rectilinear grids in Matlab by overlaying grid extents over shoreline features and specifying the number of cells in the X and Y directions. One can then drag the boundaries of these grids to improve grid orthogonality, change cell size in sections of the grid, or include or exclude topographic features represented by the shoreline displayed in Matlab.

For each Scoping Study area, a point shapefile was created that included a specified river extent as well as the outline of the estimated 100-year Floodplain. The Area 1 shapefile included points extending from the Gordonville Road Bridge downstream to the Freeland Road Bridge. The Area 2 shapefile included points extending from the Tittabawassee Road Bridge to the Center Road Bridge. The point shapefiles were used to generate a set of discrete latitude/longitude points for use as shorelines within SeaGrid.

For Area 1, an initial 50-by-30-cell model grid was developed that extended from approximately 850 feet downstream of Gordonville Road to 10,500 feet upstream of Freeland Road and was 11,070 feet in length. After initial model simulations, a more detailed model grid was developed for Area 1 so that the river would be better represented with the grid. This refined Area 1 grid was a 211-by-55-cell model grid that extended from approximately 2,950 feet downstream of Gordonville Road to 10,600 feet upstream of Freeland Road and was 11,775 feet in length. Figure D-1 details the complete final Area 1 grid and associated shoreline and floodplain and Figure D-2 details a subsection of the grid near Area 1.

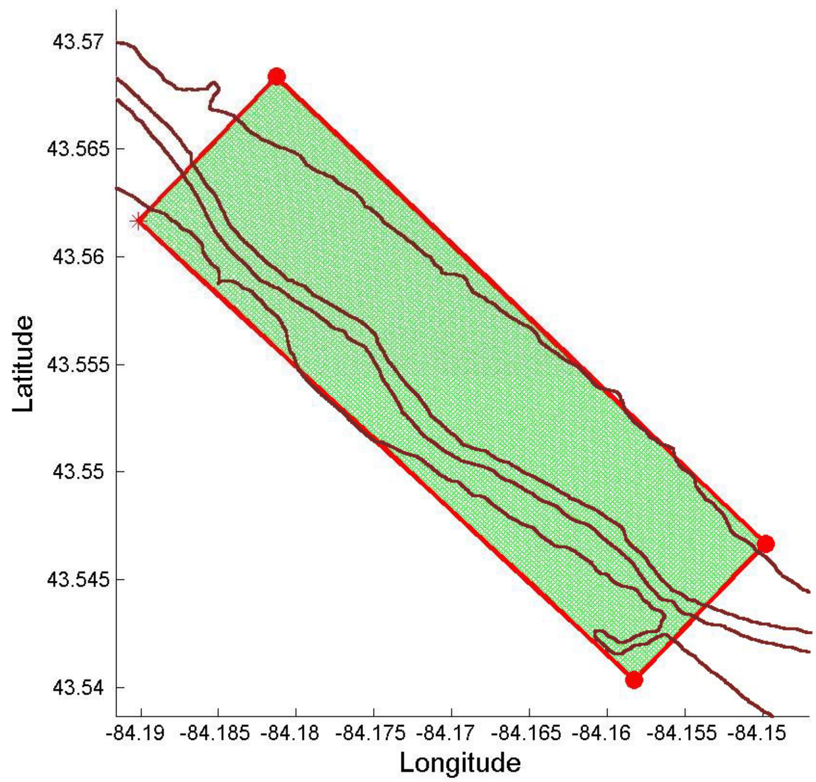

FIGURE D-1
EXTENT OF AREA 1 MODEL GRID AND SHORELINE

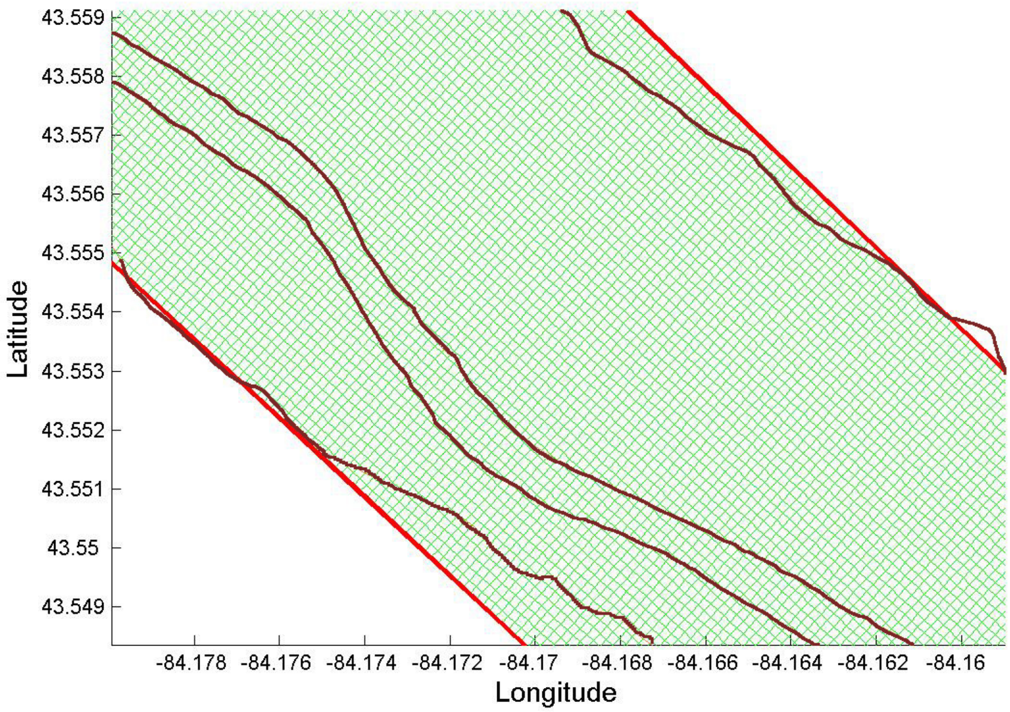

FIGURE D-2
AREA 1 MODEL GRID AND SHORELINE AT THE AREA 1 SITE

For Area 2, a 280-by-138-cell model grid was developed that extended from the Tittabawassee Road Bridge to the Center Road Bridge. This grid was aligned with the prevailing floodplain axis from northwest to southeast. Cells were masked out in both grids that were outside the floodplain or remained dry after initial model runs to decrease the computational time needed. Figure D-3 details the entire Area 2 grid and associated shoreline and floodplain and Figure D-4 details a subsection of the grid at Area 2.

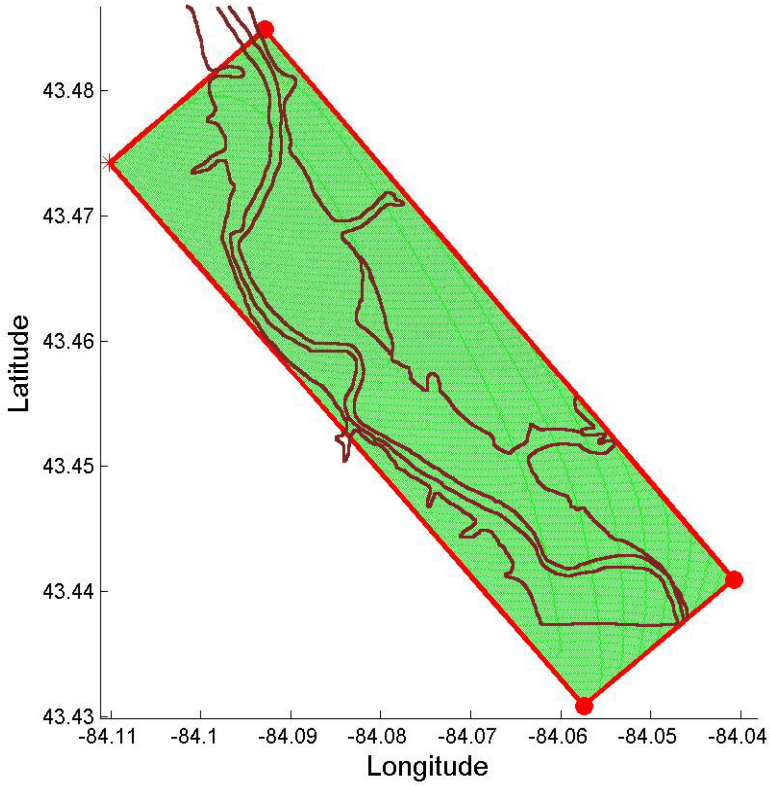

FIGURE D-3
EXTENT OF AREA 2 MODEL GRID AND SHORELINE

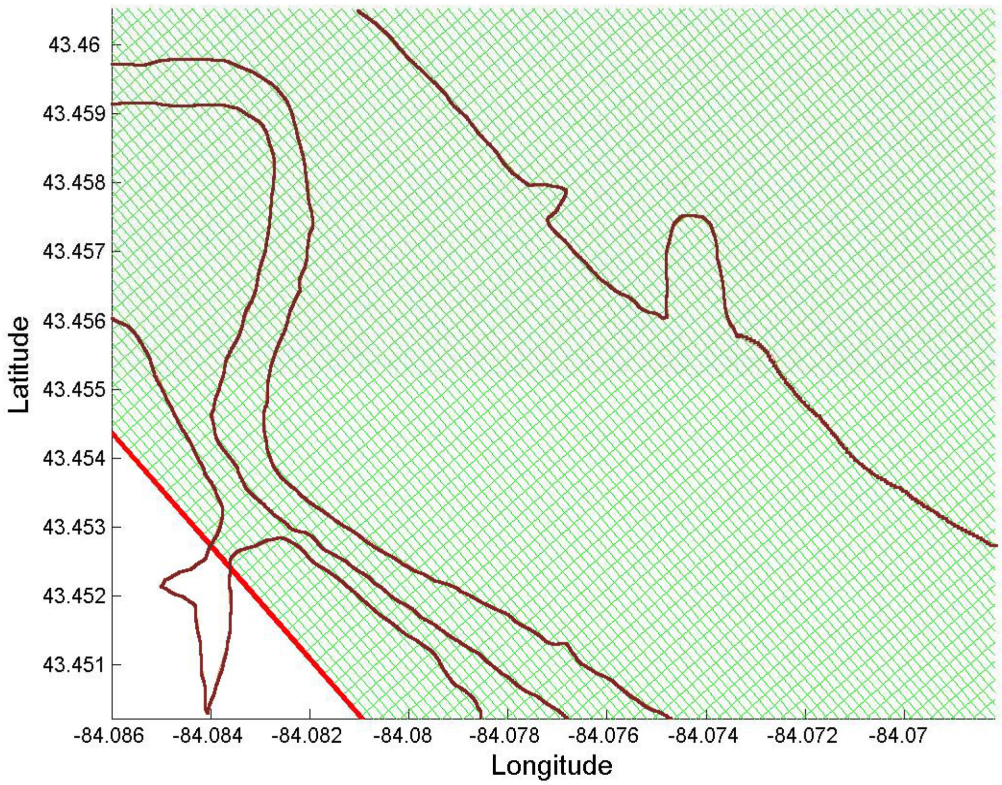

FIGURE D-4
AREA 2 MODEL GRID AND SHORELINE AT THE AREA 2 SITE

The final grids for Area 1 and Area 2 represented the river sections near both study areas with at least three, and usually four, cells across the width of the river channel.

EFDC Model Configuration

Study Area Model Roughness Estimates

Land use coverages for each model domain were created using geographical information system (GIS) and digital photos of the area. The fractional area of each model cell containing forest, field, and river were calculated based on this information. Roughness factors selected for the three land use types were 0.008 meters (m) for forest, 0.004 m for field lands and 0.002 m for the riverbed. A composite roughness factor for each model cell was calculated based on the area of each land use in each cell for both the Area 1 and Area 2 models. Roughness factors used for this modeling effort were very conceptual in nature, and roughness values should be refined for future modeling efforts.

Model Topography and Bathymetry

Topographic and bathymetric elevations for each model domain were created using GIS. A topographic data set was developed by CH2M HILL using a combination of Light Detection and Ranging (LiDAR) and photo control survey data collected for the Tittabawassee River floodplain. Breaklines were added at major topographic features within the floodplain to aid in contour development. The final topographic data set met National Map accuracy standards for a 100 feet/inch scale map with 2-foot contours. Bathymetric cross section and longitudinal bathymetric transects were collected by Limno-Tech (LTI) in December 2003 using boat-mounted sonar and differential geographical positioning system (GPS) correction. Measured depths were then converted to elevation by using logged water surface elevations at 6 bridge-based level monitoring locations located along the river from the Currie Parkway Bridge crossing upstream to Center Road downstream. The accuracy of the bathymetric transect data collected is assumed to be approximately 1 foot in the vertical and 1 m in the horizontal. The collected bathymetric data were then interpolated by CH2M HILL using linear triangulation to establish Tittabawassee River riverbed elevations at all river locations. A composite topographic and bathymetric data set was then developed by CH2M HILL and sent to LTI in Triangulated Irregular Network (TIN) form. A 10-foot by 10-foot average elevation Environmental Systems Research Institute (ESRI) grid was next developed from this TIN file for the entire Tittabawassee River and floodplain. Both the Area 1 and Area 2 model grids were then overlaid on the created ESRI grid and area-weighted elevations were estimated for each model grid cell.

Cell Masking. All model cells located outside the estimated 100-year Floodplain and selected high-elevation cells on the edges of the floodplain that remained dry during high flow-simulation periods were masked to reduce the computational time required by the model.

Boundary Conditions. Conceptual upstream flow and downstream water surface elevation (WSE) boundary conditions were created for each model. All models developed were first initialized with all unmasked cells submerged, requiring a higher upstream flow rate and a very high downstream WSE. Unmasked cells needed to be submerged at the start of initial model simulations because there is no provision in EFDC to start initial model simulations with dry unmasked model cells. Model WSEs and flows were then lowered until a representative flow rate was reached. Subsequent model simulations could be started with lower WSE elevations and flows through the use of a model hotstart file that recorded what cells were dry or wet, reducing model simulation times. Representative flow rates differed for the various model runs; however the final models produced for both Area 1 and Area 2 were reduced to a low flow rate of 2,500 cubic feet per second (cfs), which was held constant until steady-state conditions could be established within the model domain. Model flows were then linearly ramped up over 2 days until the March 2004 flood peak of 23,945 cfs was reached. This flood peak was measured at the Tittabawassee River USGS gage 04156000 at Midland, MI. The peak flow rate was held constant for 12 hours, and flows were then linearly decreased over 2 days to 2,500 cfs. The rising limb and flood peak simulated in the model matched well with the rising limb and peak flows measured at the USGS gage at Midland, MI during the March 2004 flood, enabling the inundation phase and peak flows expected at Areas 1 and 2 to be simulated with a high degree of confidence.

The downstream boundary conditions were developed using the WSE/discharge curve for gage 04156000 and WSEs recorded along the Tittabawassee River at the Gordonville Road and Freeland Road Bridges during the March 2004 flood event. WSE measurements recorded at each site were taken at roughly the same time. Using the WSE measurements recorded at Gordonville and Freeland Roads and the distances between these roads and the downstream boundary of each model, a WSE was estimated for the downstream end of each model at the time of measurement.

The timestamp recorded during the March 2004 event WSE measurements was then associated with the flow rate recorded at the same time period at the Tittabawassee River gage at Midland. This flow rate and the calculated WSE at the model downstream boundary were then used to adjust the WSE/discharge curve recorded at the Tittabawassee River gage to the appropriate elevation. Once this was done, a time series of WSEs corresponding to the flows being input at the upstream end of the model could be calculated for each model downstream boundary. Model flows and WSEs are shown in Figure D-5.

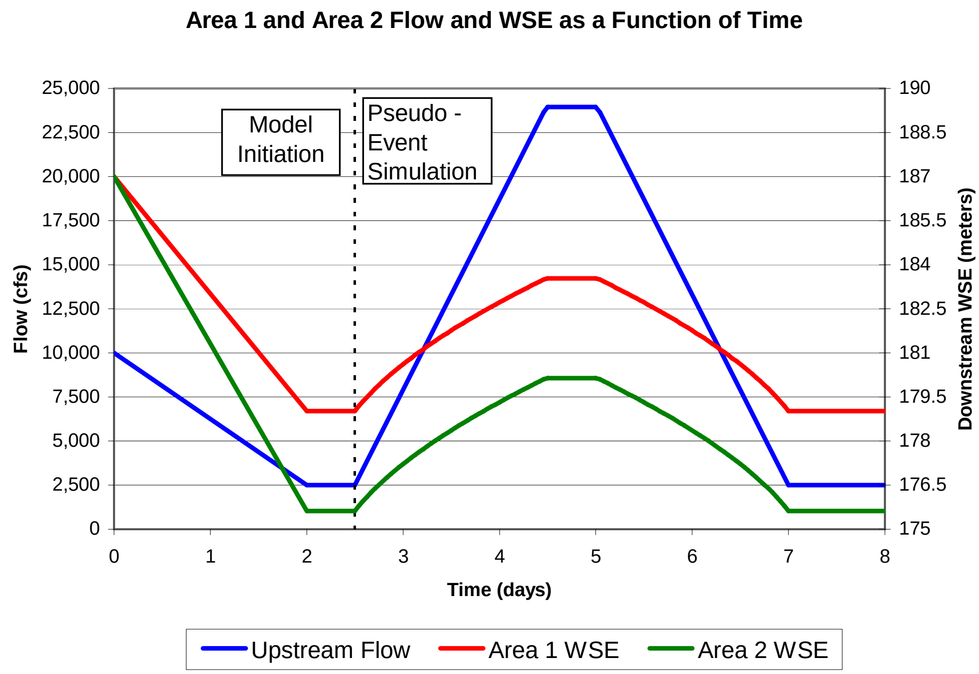

FIGURE D-5
FLOW AND WSE VALUES USED FOR AREA 1 AND AREA 2 EFDC MODELING

EFDC Model Application. Simulations for both Area 1 and Area 2 were created to represent the March 2004 flood event, using the boundary conditions described previously. Velocity and bottom shear time series were output for both simulations. The velocity time series for both Area 1 and Area 2 were then imported into Matlab, and streamlines were generated using the velocity data to predict sediment transport pathways from the riverbank to sample sites within each study area. Figures D-6 and D-7 display some of the streamlines generated for Area 1 and Area 2. All simulation results generated for these conceptual models are preliminary model results and should be considered draft.

FIGURE D-6
AREA 1 STREAMLINES GENERATED FROM EFDC MODELING OUTPUT

FIGURE D-7
AREA 2 STREAMLINES GENERATED FROM EFDC MODELING OUTPUT

References

U.S. Environmental Protection Agency (USEPA). 2001. EFDC1D - A One Dimensional Hydrodynamic and Sediment Transport Model for River and Stream Networks: Model Theory and Users Guide. September.